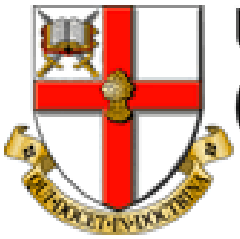

University of Chester

Comparison of distance travelled, speed and heart rate among three outfield positions in amateur female hockey players

Dissertation submitted in accordance with the requirements of the University of Chester for the degree of Master of Science

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Angie Boran

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Abstract

The aim of this research is to observe physical demands of amateur female hockey players during a hockey match. The research compares distance travelled, speed and heart rate (HR) between the three playing positions (forward, midfield, defence). Spencer, Rechichi, Lawrence, Dawson, Bishop and Goodman (2005) state that published research on physical demands of hockey is limited. There is even more limited research on women's hockey and none based at amateur club level competition. SPIproX Global Positioning System (GPS) was used to measure the physical outputs of players during amateur female field hockey matches. Players were observed during competitive club level hockey matches over two thirty-five minute halves. The 36 players played in three different divisions 5, 9 and 13 of the Irish Leinster hockey league (age 28 ± 8.40 years, height 166 ± 7cm, body mass 63.0 ± 7.8kg; mean ± SD). Twelve players were randomly selected from each position (forward, midfield, defence). The mean distance covered per position was 6009 ± 796m for forwards, 6660 ± 542 m for midfield and 5896 ± 801m for defence. The results show that all midfield players have higher mean speed, (1.66 ± 0.12m/s), than all forwards (1.58 ± 0.14 m/s) and defence (1.53 ± 0.19 m/s), though not significant ($P > 0.05$). Midfield players (169 ± 17 bpm) and forwards (169 ± 8 bpm) have higher mean HR, than defence (162 ± 15 bpm). The defence were the most unique of the positional groups. They covered the least total distance, had the lowest average speed and lowest HR responses. The results, though lower, concurred with most of the literature reviewed in terms of positional differences in physical outputs and physiological demands. Differences in amateur versus international status may reflect differences in the findings in the current study. The implications of the current study suggest that position specific training and conditioning may be required. The lower level of physical outputs may suggest that training at elite level versus amateur level need to be specific to the level of the players.

Declaration

This work is original and has not been submitted previously in support of a degree qualification or other course.

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Chapter 1 - Introduction

Field hockey is a physically challenging team sport where physiological demands are considerable. Lythe and Kilding (2011) state that modern day elite hockey is a physically demanding team sport. There are important differences between the three outfield positions of hockey (forwards, midfield and defence) which may impact on their training and selection. Forwards need to run at speed, midfielders need higher levels of aerobic fitness, while defenders need to keep up with forwards and possess agility. To be successful in field sports, players generally require high levels of endurance, strength, speed, flexibility, agility and coordination. A better understanding of these abilities and their interrelationships will help both athletes and coaches understand the necessary fitness to cope with these demands and plan sport-specific training programs. The fundamental aim of training is to improve competitive performance, making quantification of training of utmost importance when programming training sessions that allow for optium preparation of sportspersons. Quantification of the outputs of players provides a useful framework on which to develop and plan training practices, performance, substitution, while also helping to motivate players, promote more competition, boost morale, tactical solutions with reference to players' capabilities. Lythe and Kilding (2011) stated fullbacks covered significantly less total distance than all other positions. They state the difference in physical outputs observed for some positions suggests position-specific conditioning is required at the elite level. Gabbett (2010) states that midfielders covered greater distances than strikers and defenders. Spencer, Lawrence, Rechichi, Bishop, Dawson and Goodman (2004) states that limited information exists about the movement patterns of field-hockey players.

The current study will endeavour to address a number of the gaps that exist in the literature reviewed. Information on female amateur hockey players in Ireland will be recorded for the first time. Comparisons can now be investigated between elite female hockey players and amateur female hockey players. The current study will take into account the recent rule changes which would not be a part of most previous studies. It will contribute to the development of the quantification of the physical outputs of the positional player roles (forwards, midfield, defence). This will provide useful and objective information on the physical demands required. It will provide a useful framework and information for amateur coaches for devising and manipulating session plans in order to maximise player and team performance. A greater understanding over positional performance and capabilities will be provided. The feedback leads to the development of informed coaching interventions and feedback for the players. The information may prove critical in finding that extra margin between success and failure. GPS makes it possible for coaches to gather, analyse and use the information and resources more effectively in order to improve training, decision-making and collaboration. Researchers Reilly and Borrie (1992), Boyle, Mahoney and Wallace (1994) reported that recording physical activity and measurement of different physiological parameters of players during a match can be useful to estimate demands during a field hockey game.

Hockey is described as a field-invasive game by Reilly and Borrie (1992). According to Boyle et al. (1994) and Reilly and Borrie (1992) field hockey is a competitive, high–intensity, intermittent team sport game, which places significant aerobic demands on players. Hockey is played between two teams of eleven players, including a goalkeeper. The pitch is a 91.40 metres x 55 metres (100 yards x 60 yards) rectangular field and a match consists of two, thirty-five minute halves, with a five to ten minute interval break. Hockey has had significant

modifications. In the 1970's the playing surface changed from grass to artificial turf which altered the pace and style of the game. More recently, the rules have changed to modify the pattern of the game. The two most significant changes (mid-1990s) have been to allow unlimited substitutions (a maximum of 16 players can play in each match and can rotate as frequently as they like) and the removal of the offside rule (which has created attacking space and led to more goals being scored per match). In 2009 the auto-pass was introduced which allows quick and immediate play from a free hit. Spencer et al. (2004) explain that these changes were initiated to promote fast-paced, continuous play. These changes have altered the tactical and physiological demands of the game. Anders and Mayers (1999) state that field hockey has become a swift and skill based game.

Literature Review

Positional Differences

Deutsch, Kearney and Rehrer (2007), Duthie, Pyne and Hooper (2005), James, Mellalieu and Jones (2005) explain that the desire for position specific training has driven the investigation into the positional demands of sports. The positions of hockey can be divided into four categories; goalkeepers, defenders, midfielders and forwards and each have specific roles and activities. Although there are many options, a typical team formation is shown below (figure 1.1) with a goal keeper, four defenders, three midfielders, three forwards. Reilly and Borrie (1992) explain that the evolution of playing formations within hockey initially followed the same pattern as in soccer. Reilly and Thomas (1976) reported that distance covered by players in the English football league varied depending on their positional role and outfield playing formations. Jennings, Cormack, Coutts and Aughey (2012) state that as with soccer,

field hockey categorises players in three distinct positional groups (strikers, midfielders, and defenders).

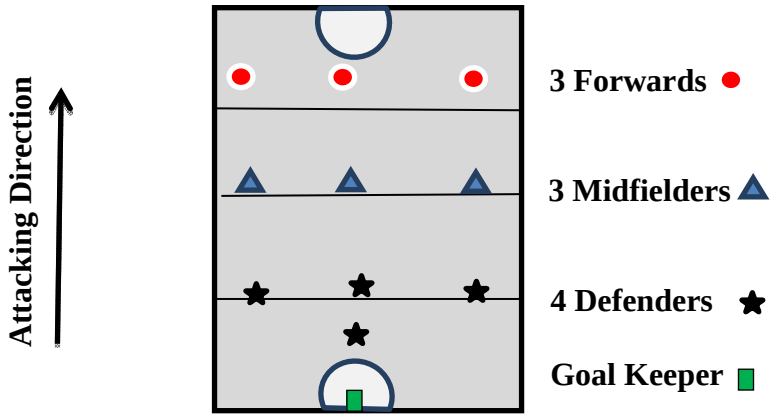

Figure 1.1 Typical field positions in hockey

In hockey, it appears that there are small differences between the physical characteristics of different positions although there is inadequate published data on modern players to confirm this. However, Johnston, Sproule, McMorris and Maile (2004) reported that match work rates do differ between positions. Johnston et al. (2004) reported midfielders having highest HRs (167 ± 5 b.min-1) with defenders the lowest (147 ± 13 b.min-1) although the work (cruising and sprinting) to rest (standing, walking, jogging) ratios were similar across positions with defenders 1:6.1, midfielders 1:7.3, and attackers 1:5.2. Spencer et al. (2004) found differences in match playing time and motion frequency between positions. Inside-forwards played the most match time, (18 minutes more than the half-backs). The most notable was the higher number of sprints performed by the inside forwards and strikers (39 ± 1 and 42 ± 15, respectively) compared with the fullbacks and halfbacks (18 ± 1 and 22 ± 7, respectively).

Performance Assessment for Field Sports

According to Carling, Reilly and Williams (2009), in field sports, players must now move faster, anticipate better, demonstrate greater levels of technical and tactical ability and persist longer that competitors from the past. The commitments made by club, coach, and player in attempting to reach perfection and the basis for training and competing are no longer just on simple views of how the player performs. Fundamental to performance in field sports is the need to capture, analyse and evaluate information on key areas such as physical capacities of players. This feedback leads to the development of informed coaching interventions and for the players. The combined approach may prove critical in finding that extra margin between success and failure. The provision of feedback is part of the coaching process and failure to provide feedback to which players perform, or simply basing and planning interventions on subjective observations on how a player is performing can reduce any chance of improvement. Katz (2001) states that modern technology makes it possible for coaches to gather, analyse and use the information and resources more effectively in order to improve training, decision-making and collaboration.

Konarski, Matuszynski and Strzelczyk (2006) and Reilly and Borrie 1992 explained that modern training in different sports is based on many different variables assessed during training and competitions. Researchers Reilly and Borrie (1992) and Boyle et al. (1994), state that recording physical activity and measurement of different physiological parameters of players during a match can be useful to estimate demands during a field hockey game.

Pollard (2002) points out that monitoring athletes during competition to develop an understanding of physical demands has evolved considerably since the 1950's and 1960's.

Current systems and methods have become very advanced and a growing number of time-motion analysis (TMA) studies have been conducted in sports such as soccer (Bangsbo, Norregaard & Thorsoe (1991), Rienzi, Drust, Reilly, Carter & Martin (2000), Krustrup, Mohr, Ellingsgaard & Bangsbo (2005), Di Salvo, Baron, Tschan, Calderon Montero, Bachl & Pigozzi (2007)). However, MacLeod, Bussel and Sunderland (2007) state that there has been limited study of the physical demands of hockey since rule changes have been implemented, especially at the elite level.

Realiability and Validity of the Global Positioning System (GPS)

The Global Positioning System (GPS) provides 24 hour, all-weather navigation and surveying capability worldwide. From a sporting perspective, it is the relative positioning accuracy (how far the person has travelled, their speed and time over a set course) that is of real interest to the coach and player. According to Carling et al. (2009), GPS has begun to impact on the analysis of performance in various field sports. The GPS worn by players in training and competition draw on signals sent from at least four of the earth orbiting satellites to determine positional information and therefore, calculate movement speeds, distances and pathways. These data are stored in the GPS before being downloaded onto a computer for analysis by means of specific software. The GPS system SPI proX used is designed by Australian company, GPSports Systems Limited and is used specifically for professional team sports. The GPS tracking units are marketed for use with team-sport athletes to monitor their training and competition. They are currently used by teams competing in English Premier League Football, Professional Rugby Union. GPSports products are used by some of the best field hockey nations in the world for example, China, UK, New Zealand and Canada embracing GPSports technology.

The unit is carried by the individual in a purpose built sports vest with an integrated garment for housing the unit just below the back of the neck. The GPS is relatively small, a typical GPS system is now no larger than a small mobile phone and therefore makes it easy to wear. (76 gram unit, size 48mm x 20mm x 87mm – flat design). The GPS unit captures speed and distance data at 15Hz. The GPS is capable of storing data on HR and records information on the frequency and intensity of impacts such as tackles. The reliability and validity of portable GPS devices has been reported in studies by Macleod et al. (2007), MacLeod, Morris, Nevill and Sunderland (2009) stating that GPS technology provides accurate measures of speed and distance covered during the activity categories identified in team sports.

MacLeod et al. (2009) state that the scarcity of research into the physiological demands of women's field hockey has inhibited the development of a scientific approach to preparation for competition at any level of field hockey. GPS have the potential to further an understanding of the physiological demands of competitive sport through tracking player movement patterns. GPs will provide data on the physiological demands of the sport which will help in training specificity and can be used to optimise players' performance, workload and goals. Edgecomb and Norton (2006) state that the use of a GPS provides a quick and accurate way to describe and analyse the physiological demands of sport. Gray, Jenkins, Andrews, Taaffe and Glover (2010) state that despite relativelley few independent studies of the validity and reliability of global positioning system technology in sport-related conditions, GPS receivers are gaining popularity in a number of sports as a means for coaches to assess specific movement demands of their athletes in both training and competition. Table 1.1, Appendix A illustrates the key benefits of GPS technology for field hockey.

Distance, Speed and HR

Spencer et al. (2004) report that published research on physical demands of hockey is limited especially relating to recent competition. There is even more limited research on women's hockey and none based at amateur club level competition. They state that limited information exists about the movement patterns of field-hockey players. A brief summary of the research studies from men's and women's hockey is presented in Table 1.2.

Table 1.2. Summary of Research Studies of Elite Men's and Women's Hockey

Study Reference	Participants	Results
Boyle et al. (1994)	9 Northern Irish International players	Mean HR during match play = 158.6 ± 8 bpm.
Boddington et al. (2002)	23 Female hockey players	97.4% in low intensity activity. Player movement < 4 km, with a mean of 3901 ± 522 m.
Johnston et al. (2004)	15 Scottish domestic players	Percent of time spent standing 4.0%; walking 50.9%; jogging 29.6%; cruising 10.1%, sprinting 4.7% . Mean HR during match = 143.4 ± 15.3 bpm.
Spencer et al. (2004)	14 Australian International players	Percent of time spent standing 7.4%; walking 46.5%; jogging 40.5%; striding 4.1%, sprinting 1.5%.
Spencer et al. (2005)	14 Australian International players.	Percent of time spent standing 11.2%/15.5%; walking 47.7%/48.3%; jogging 34.8%/29.4%; striding 5.1%/5.8%, sprinting 1.2%/1.0%
Paun et al. (2008)	6 Australian domestic players	Mean total distance covered 6419 ± 838 m. Mean HR during match play 176 ± 13 bpm.
MacLeod et al. (2007)	12 elite female outfield players. 4 defenders, 4 midfield and 4 forwards.	90% spent in low intensity activity. A significant decrease in average HR in second half (174 ± 12 beats·min^{-1}).

MacLeod et al. (2009)	5 male and 4 female participants.	The mean distance recorded by the GPS system was 6821 m (s=7) and the mean speed was 7.0 km · h^{-1} (s=1.9).
Gabbett (2010)	14 elite women field hockey players	On average, players covered 6.6 km during a match. Midfielders spent more time and covered greater distances in high intensity running (i.e., .5 $m.s^{-1}$) than strikers and defenders.
Lythe and Kilding (2011)	18 outfield players	Mean total distance covered by each individual player was 6798 ± 2009 m. Fullbacks covered significantly less total distance than all other positions. ($P<0.05$)
Macutkiewicz and Sunderland (2011)	25 elite women field hockey players	Forwards spent a greater % of time at high intensity and covered a greater % of total distance sprinting than the other outfield positions.
Jennings et al (2012)	16 elite Australian male field hockey players. International versus National level	Defenders covered less total distance compared with strikers and midfield. International players covered a greater total distance and HSR distance than the national level competition.

Boyle et al. (1994) investigated HR response when studying the work rates of international hockey players in Northern Ireland. HR was recorded at 5 second intervals during club competition and referenced to HRs measured during a laboratory test of maximum oxygen consumption. Mean HR during match play was 159 ± 8 $b.min^{-1}$. However this study was limited as the sample size was very small with only nine subjects monitored (one player per game for nine games) and no individual playing position had two sets of data.

Boddington, Lambert, St. Clair Gibson and Noakes (2002) aimed to reassess the work profile of women's hockey and presented research on the modern contemporary game. Calculating time spent and mean movement during the game, the authors reported that hockey players spent 97.4% of total game time in low intensity activity (standing 2 ± 0.3%; walking 82 ± 2%; jogging 14 ± 2%). The remainder (2.6%) was attributed to cruising and sprinting, 2 ± 0.4% and 0.7 ± 0.1% respectively. Player total distance covered throughout the game was deemed to be less than 4 km, with a mean of 3904 ± 522 m in 63.4 ± 9.5 minutes of play. However, a limitation was that player distance was recorded only every 15 seconds and time spent performing discrete activity was not recorded. Hence, there is limited understanding of the physiological demands of women's field hockey because of the lack of research, variability in methods used and differences in movement categories that makes comparisons difficult.

Similar to Boyle et al. (1994), Johnston et al. (2004) studied elite male hockey players in the Scottish National League. Fifteen players were filmed, one player per match, for fifteen weeks providing fifteen sets of data. Findings from single measurements were only reported. Players spent the majority of time stationary (4.0%) or engaged in low intensity activity (walking 50.9%, jogging 29.6%) with only a small portion of the match in high intensity activity (cruising 10.1%, sprinting 4.7%). Mean HR was 155 ± 12 bpm and 64% of match time was spent above 75% of maximum HR. Players had an average of 30 ± 6 sprints with average sprint duration of 5.7 seconds. Johnston et al. (2004) reported that the proportion of time that was spent either stationary, walking or jogging suggest that the game consists of short bursts of high intensity work within an aerobic framework.

In elite players Spencer et al. (2004) filmed players to describe the physical work rates of hockey players during an international match. The mean match time of each player was 48 minutes. Similar to the findings of Johnston et al. (2004) low intensity activities of standing walking and jogging accounted for approximately 95% of match time (7.4% standing, 46.5% walking, 40.5% jogging). Mean sprint duration was 1.8 seconds with an average of 30 ± 12 sprints per player and the match consisted of 780 motions or a change in activity every 5.5 seconds. The number of sprints recorded per player is similar to that reported by Johnston et al. (2004) but the sprints duration is lower (1.8 seconds versus 5.7 seconds). Spencer et al. (2004) reported that more sprints were performed by inside forwards and strikers compared with the full-backs and half-backs and there were differences between positions in activity frequency for striding and jogging.

Another common point of discussion in time-motion studies is changes in motion. Paun, van der Ploeg and Stern (2008) used SPi10 GPS units to measure the movement patterns and physiological demands of hockey match play in elite Australian domestic competition. The average time that each player spent on the pitch during each match was 64 minutes (the remaining time was spent resting on the side line while substituted) and total distance covered by players during this time was 6419 ± 838m. Players spent 89% of match time engaged in low or moderate intensity activity (standing, walking and jogging) with the remaining 11% in high intensity activity. An average of 36 ± 9 sprints were performed per player per match with a mean duration and distance of 2.5 ± 1.7 s and 12.4 ± 9.9 m respectively. Spencer et al. (2004) reported 780 motions or a change in activity every 5.5 seconds, while Paun et al. (2008) reported 901 ± 116 motion changes. The findings compare well to those of Spencer et al. (2004), despite methodological differences.

Although these two recent studies have provided a basic understanding of the physical demands of men's elite hockey there are methodological differences between them. There are also short-falls in both these studies with a small number of matches used by Spencer et al. (2004) and the small number of players studied by Paun et al. (2008). Consequently there is a need for another comprehensive set of data that covers all playing positions for a number of matches to adequately describe the demands of top level of competition and the equivalent in female hockey.

MacLeod et al. (2007) recently investigated the physiological demands of national-league female field hockey players using time-motion analysis (TMA). MacLeod et al. (2007) carried out a study to build on current knowledge of the physiological demands of women's field hockey, under the modern rules. MacLeod et al. (2007) state that research into the TMA of women's field hockey is scarce. They stated that it is imperative that athletic preparation is based on sound proven research. Their investigation provides comprehensive analyses of women's elite level field hockey. Twelve elite female outfield players (age 22 ± 3 years) from the women's English National League were videoed for the entire duration of a game. All participants were field players; four defenders, four midfielders and four forwards. The main finding of this study was that players spent the majority of the game engaged in low-intensity activity (92.1%) , (11.4% standing, 45.1% walking, and 35.6% jogging) and 7.9% comprised high-intensity exercise (5.1% cruising, 1.5% sprinting, and 1.3% lunging). This value is smaller than the 97.4% reported by Boddington et al. (2002). Figures of 78% have also been reported by Lothian and Farrally (1994) which suggest that the differences may be due to rule modifications, in the case of the latter study, and variations in motion classification for the former study. High intensity activities of cruising, sprinting and lunging accounted for 7.9% of game time. This figure of 7.9% is higher than the 2.6-5.6% reported in

literature of Boddington et al. (2002), Spencer et al. (2004) and Spencer et al.(2005). The study showed the mean HR of 172 ± 11 beats·min^{-1} during competition was higher than the reported values of 155-159 ± 8 beats·min^{-1} by Boyle et al. (1994). A decrease in HR was recorded in the second half (174 beats·min^{-1} versus 169 beats·min^{-1}). This signifies a drop in work rate in the second half. It is noted in the study that few differences occurred between midfielders and forwards in terms of work rate and may be due to the modern more fluid attacking formation involving frequent interchange and player versatility. MacLeod et al. (2007) states however, that the research is based on 12 elite field hockey players and therefore further research is required to build a data base to develop a comprehensive understanding of the demands of women's field hockey.

A recent study by Gabbett (2010) used a GPS system analysis to quantify the demands of elite hockey. This study by Gabbett (2010) only focused on female elite players. The author stated that midfielders covered greater distances than strikers and defenders. Players covered 6.6 km on average over the course of the match. Previous studies by Gabbett and Mulvey (2008) and Spencer et al. (2005) of high-intensity intermittent team sports (e.g., soccer, field hockey) have reported that players cover 9-12 km and perform 19-62 sprints in a match.

According to Lythe and Kilding (2011) although several TMA studies exist for field hockey (Boyle et al. (1994), Gabbett (2010), Lothian and Farrally (1994), Spencer et al. (2004) and Wein (1981)) significant changes to the game have occurred which may limit the usefulness of some older studies. Malhotra, Ghosh and Khanna (1983) demonstrated that the physical demands of playing hockey on Astroturf was substantially greater (18%) than playing on grass. Wein (1981) reported an average match distance of 5610 m for men during elite competition matches. Lythe and Kilding (2011) suggest that this relatively low distance

reported by Wein (1981), as compared to their study may reflect that the data was collected before changes to the playing surface and new rule changes were made as well as advances in conditioning practices in recent years.

A study conducted by Lythe and Kilding (2011) on New Zealand elite men's hockey shows that the mean total distance covered by each individual player was 6798 ± 2009 m. The matches were played on water-based pitches. GPS data, heart rate data and video footage were collected. The mean total distance covered per position for 70 minutes was 8160 ± 428 m. The distance covered per position (70 minutes) decreased by 4.8% between the first and second halves ($P < 0.05$). The fullbacks covered significantly less total distance than all other positions. ($P < 0.05$) High intensity running (>19km.h^{-1}) comprised 6.1% (479 ± 108m) of the total distance covered and involved 34 ± 12 sprints per player, with an average duration 3.3seconds. The average heart rate was higher in the first half (86.7% HR_{max}) than the second half, (84.4%HR_{max}), though this was not significant ($P=0.06$). The authors suggest that modern day elite hockey is a physically demanding team sport. The difference in physical outputs observed for some positions suggests position-specific conditioning is required at the elite level.

Macutkiewicz and Sunderland (2011) recently investigated the activity profiles of elite women hockey players during match-play. Elite women field hockey players (25) were analysed for 13 international matches using GPS. The study assessed the activity characteristics of elite female hockey players and to demonstrate that these characteristics differ according to playing position. The results showed that forwards had notably different activity patterns than midfielders and defenders. The results demonstrated that elite women hockey players cover a mean distance of 5541 ± 1144 metres in 48 ± 4 minutes. The distance

covered by high-intensity running and sprinting was 853 ± 237 metres and 232 ± 96 metres respectively. Forwards spent a greater percentage of time running, fast running, and sprinting than midfielders and defenders. Differences in activity were observed between positions, with the activity profile of forwards differing considerably from that of defenders and midfielders. Forwards spend a greater percentage of time performing moderate and high-intensity exercise, such as running, fast running and sprinting, and less time walking. The amount of low-intensity exercise reported in the present study is below the 97%, 95%, and 92% reported by Boddington et al. (2002), MacLeod et al. (2007), and Spencer et al. (2004) respectively. The difference can be attributed to the activity characteristics used to describe the intensity of exercise. This study is the first to provide a detailed analysis, using GPS, of the distances covered and time spent performing various activities during a match and the influence of the continuous substitution rule on the physiological demands imposed on players. The findings show that forwards had different activity patterns than midfield and defence. Forwards spent a greater percentage of their playing time at high intensity and covered a greater percentage of total distance sprinting than the other outfield positions.

Jennings et al. (2012) recently investigated the differences between Australian men's national level and international level competitions using GPS technology. Specifically, the level of competition playing position and differences between first half and second half were investigated. Players were separated into 3 distinct groups (strikers, midfielders, and defenders) for positional comparison. When comparing international and national players they demonstrated that the total distance travelled independent of positional groups was 9776 ± 720 m and 8589 ± 623 m for international matches and national level Australian hockey league matches respectively. They stated that within the national leagues there were no differences between strikers and midfield for total distance but the defenders covered less

total distance compared with strikers and midfield (8.1 ± 3.6% and 8.4 ± 2.6 %; 36.1 ± 11.1% and 51.5 ± 12.1%, respectively). According to Jennings et al. (2012) this is the first study to have investigated the activity demands of national level competition or compared these with the top level international competition. The main findings of the study stated that international players completed more high speed running (HSR) across all positions than players at an elite national level. In both competitions, midfielders and strikers performed more HSR than defenders, and the activity demands of players decreased in the second half. International players covered a greater total distance and HSR distance than the national level competition.

Although, the most recent hockey TMA studies have provided a basic understanding of the physical demands of men's and women's field hockey, limited information and gaps in the literature and information exist with regard to amateur female hockey players. All of the literature reviewed concerns elite hockey players. To the author's knowledge no equivalent study exists for amateur female hockey players. To date no study has documented the physiological demands with regard to distance travelled, speed and heart rate in amateur female hockey players. No research has been carried out within Irish hockey using GPS analysis techniques as previously validated in hockey by MacLeod et al.(2007), (2009). Most analysts refer to soccer when trying to develop concepts and enhance their own performance analysis methods. Hockey shares many tactical and structural similarities with soccer (Reilly & Borrie, 1992). However, compared to soccer the volume of research and investigation in hockey is limited. There have been some studies as mentioned earlier by Spencer et al. (2004), Macleod et al. (2009), Lythe and Kilding (2011) that have provided information on elite performance. This suggests that there is an opportunity to gain knowledge and possibly improve performance through analysis.

The objectives of this study were to compare the distance travelled, speed and HR of forwards, midfield and defence by using methods of performance analysis with GPS to measure the physical outputs of players during amateur female hockey matches. The research is to find out how, if at all, the three variables differ between the forwards, midfield and defensive players. There has been limited research performed on hockey, especially at amateur female club level. This study investigated the physiological demands of amateur female club level hockey players. The perception may likely be that midfield works harder than all other positions in all three variables. The research looked at whether there is a need for position specific training or conditioning between midfield, forwards and defence and between amateur versus elite level hockey players.

Hypotheses

1. Midfielders will cover greater distance and defenders will cover the least distance.
2. Midfielders will achieve higher speeds and defenders will achieve lower speeds.
3. Midfielders will achieve higher heart rates and defenders will achieve lower heart rates.

Chapter 2 - Method

Participants

Thirty-six members of the Botanic Hockey Club (12 forwards, 12 midfield, 12 defence) based in Dublin were recruited to participate in the study. The volunteers were amateur female hockey players. The players competed from division five to division thirteen in the Leinster Hockey League. The research study was introduced to players at a club meeting and players were asked to volunteer. Based on the reponse the participants were picked randomly.

The participants were informed to take time to read the information and to seek clarification from the researcher if there was any difficulty with interpretation of the information. It was explained to the participants that the aim of the project was to investigate that the, distance travelled, speed and HR differs, if at all, between three outfield positions (forward, midfield, defence). It was explained that the use of GPS devices to measure demands in team sports was becoming increasingly popular. A better understanding of these demands would help both players and coaches understand and plan specific training programmes, performance and tactical solutions. The quantification of the outputs of players would provide a useful framework with reference to players' capabilities. It was explained to the participants that the study would contribute to the development of the quantification of the outputs of the positional player roles (forwards, midfield, defence). It was pointed out that there was no financial payment to the participants or the researcher in relation to the research.

It was stated that the research methods would take the form of structured questionnaires. The participants were given a letter of invitation to participate, a participant information sheet to keep and also asked to sign a consent form, which included a statement that they were free to withdraw at any time. The participants completed two pre-test questionnaires to obtain some health, fitness levels and baseline characteristics. It was explained that as a participant they were free to withdraw at any time without giving a reason.

The University of Chester Faculty of Applied Sciences Research Ethics Committee approved the project and written informed consent and participant information was provided to each individual volunteer participant prior to the data collection. Written permission was received from the Irish Hockey Association and Botanic Hockey Club in conjuntion with the study. See Appendix B for a copy of all forms. All games were played on an astro-turf hockey pitch, standard size (90.5 metres x 60 metres). Participant characteristics are presented in Table 2.1.

Table 2.1. Characteristics of participants

Number of Players (n = 36 female players)	
Age (years)	28 ± 8.40
Height (cm)	166 ± 7
Body mass (kg)	63 ± 7.80
Number of years hockey experience	1-4 yrs = 11% 5-10 yrs = 36% 11-20 yrs = 36% 21-30 yrs = 11% > 30 yrs = 6%
Fitness Level Questionnaire 2	Very Fit = 6% Fit = 38% Average = 56% Unfit and Very Unfit = 0%
Number of days training per week	3 ± 1

Study Design

The study design was an independent groups design with three groups. The dependent variables were distance travelled, speed and HR and the independent variable was position forward, midfield, defence. The participants were 12 players from each position (forward, midfield, defence). A stratified random sample of three players from one team in each match were anlaysed, these included one forward, one midfield and one defence; giving a total sample size of 36 players from the 12 matches. The divisions were grouped into three categories (division 5, division 9, division 13). The purpose was to investigate any differences between and within divisons at an amateur level.

Procedures

Data collection

The first stage of data collection was carried out at the start of the hockey season. The data collection was carried out over 12 hockey matches from the 12th November 2011 until the 3rd December 2011. The participants returned the completed forms prior to the commencement of the match. On a given match day three players from each position (forward, midfield, defence) played a hockey match and were fitted with the appropriate equipment. On match day before the commencement of the game the participants were fitted with the GPS unit, vest and HR monitor. The instruction given to the players was to play their match as normal. After the match the GPS unit, vest and HR monitor was returned to the researcher.

GPS Data

The data was collected using a SPIproX Global Positioning System (GPSports Systems Limited, Australia). The SPIProX equipment was supplied by Statsports, (the exclusive UK and Ireland distributor for GPSsports). The GPS system captured distance, speed and is the most advanced GPS based tracking technology on the market. The GPS recording devices were used to record the position coordinates of players at a frequency of 15 Hz (15 data points per second) and distance travelled, speed and HR data derived from the changes in position coordinates. The validity and reliability of GPS use in hockey by Macleod et al. (2009) at a frequency of 1Hz has already been documented above. The study of MacLeod et al. (2009) concluded that GPS is a reliable and valid measurement tool for assessing the movement patterns of field hockey players. MacLeod et al. (2009) study suggests that GPS system could provide a valid tool for measuring speed and distance during hockey match-play and training.

GPS Unit

A single unit was worn by each out-field player during all matches, illustrated in Figure 2.1. The small (91 mm x 45 mm x 21 mm) and light (75 g) device was worn on the upper back in a neoprene harness/sports vest under the shirt, illustrated in Figure 2.2. The neoprene harness was fitted and correctly sized for each player prior to the match so as to cause minimal discomfort and distraction. Following the conclusion of the match the data was downloaded using the Team AMS software programme. To limit error, each forward, midfield, and defensive player wore the same unit for the duration of the study. GPS data was edited to only include time spent on the field of play which was a duration of 70 minutes.

Figure 2.1 GPS SPIproX Unit **Figure 2.2 GPS Sports Vest**

In the current study the researcher administered the testing and demonstrated the equipment with the participants. The researcher carried out the data collection and data analysis. In the current study individual GPS units were worn by each player during all matches. The data was downloaded and processed using the manufacturer supplied Team AMS software programme (Statsports Team AMS v 1.2.1.0). GPS data was edited to only include time spent in play, which equated to 70 minutes playing time. The raw data was then exported to Microsoft Excel for analysis. In the current study the positions of forward, midfield and defence were tested between the variables of distance travelled , speed and HR. The data was then categorised into different outcomes in order to provide information and data relevant and dictated by the purpose of the study.

Heart rate

Each player wore a Heart Rate (HR) monitor chest strap (Team Polar, T34 uncoded, Polar Electro,Oy) which recorded HR every 5 seconds, during all matches. HR data was edited so that anlaysis did not include half-time data. Data was downloaded and processed using the

Team AMS software programme. The data was keyed to the SPSS programme and quantitative tests carried out.

Statistical Analyses

The second stage involved the analysis of the data which was completed after all 12 hockey matches were played. The information was uploaded to the software programme Team AMS. The data was then exported to Microsoft Excel and categorised into different outcomes. The quantitative tests on the data were undertaken using the statiscial analysis software SPSS (UK) Limited 1999, PASW v18. The data was keyed to the SPSS programme and quantitative tests carried out. The data was analysed to determine comparison or variance, if any, between different samples and comparison or variance, if any, within samples. The player positions (forward, midfield, defence) were analysed between distance, speed, HR, first half versus second half analysis and differences between and within playing divisions was applied to the data results. If there was a significant difference found between the data compared it was investigated further between individual samples to determine where the difference was using post hoc tests in SPSS. A series of seven different data analysis tests were carried out on the positions (forward, midfield, defence) comparing the physical outputs of distance, speed and HR.

The following investigations were carried out on distance, speed and HR:

1. Comparisons of positions; forwards, midfield and defence were determined using One Way Independent Groups ANOVA, Tukey Test and Kruskal-Wallis.
2. Analysis of the data (distance, speed and HR) between the divisions were determined using One Way Independent Groups ANOVA and Kruskal-Wallis.

3. Analysis of the data between the divisions by position were determined using One Way Independent Groups ANOVA and Kruskal-Wallis.
4. Analysis of the data of the positions (Forward, Midfield, Defence) within the divisions (5, 9, 13) were determined using One Way Independent Groups ANOVA, Tukey Test and Kruskal-Wallis.
5. Comparisons of positions; forwards, midfield and defence – first half v second half was investigated. (first half forwards v second half forwards) were determined using Kruskal-Wallis and Mann-U Whitney.
6. Analysis of the data between the divisions first half v second half were determined using One Way Independent Groups ANOVA, Tukey Test, Kruskal-Wallis and Mann-U Whitney.
7. Comparisons of distance between postions (forward, midfield, defence) in various speed zones. (zone 1-6) were determined using Kruskal-Wallis and Mann-U Whitney.

The data was analysed using SPSS. The level of data was ratio data. The research design was three groups (forward, midfield and defence). A parametric approach was adopted using the sample parameters (means, standard deviations and sample sizes). To test the significant difference between the three groups One Way Independent Groups ANOVA were run. Post hoc analysis was carried out to identify differences using the Tukey Test. If the data was not normally distributed or the assumption of homogeneity of variance was violated a Kruskal-Wallis test was carried out. Mann-U Whitney tests were carried out to ascertain any significant differences. Significance was set at $P \leq 0.05$. All data are expressed as mean ± SD. The F statistic was reported if the data was normally distributed and the assumption of homogeneity was met.

Chapter 3 – Results

The mean match time for each individual player was 70 minutes with no substitutions. The matches consisted of two 35 minute halves.

Distance

Comparison of Distance between Positions

The total distance covered by each individual player was 6188 ± 781m. The mean distance covered per position was 6009 ± 796 m for forwards, 6660 ± 542 m for midfield and 5896 ± 801m for defence as illustrated in Table 3.1. Midfield players had higher mean total distance than forwards and defence. There was a statistically significant difference observed between midfield players and defence for distance covered during a match ($F = 3.0$, $P < 0.05$). The significant difference is illustrated in Figure 3.1, Appendix C.

Table 3.1. Comparison of Distance between Positions

	Forwards	Midfield	Defence
Distance (m)	6009 ± 796	6660 ± 542	5896 ± 801

Comparison of Distance between Divisions

The mean distance covered was 6362 ± 660 m for division 5 6093 ± 686 m for division 9 and 6109 ± 991 m for division 13. Although not statistically significant ($P > 0.05$), division 5 players had a higher mean distance than division 13 players, who covered more distance than in division 9.

Comparison of Distance between Divisions by Position

The mean distance covered was 6512 ± 728 m for division 5 forwards, 5514 ± 619 m for division 9 forwards and 6000 ± 862 m for division 13 forwards. The mean distance covered was 6448 ± 412 m for division 5 midfield, 6629 ± 488 m for division 9 midfield and 6902 ± 727 m for division 13 midfield. The mean distance covered was 6126 ± 886 m for division 5 defence, 6138 ± 520 m for division 9 defence and 5426 ± 924 m for division 13 defence. There was no statistically significant difference in distance covered comparisons between forwards ($F = 1.81$, $P > 0.05$), midfield and defence between the three divisions 5, 9 and 13 ($P > 0.05$).

Comparison of Distance between Positions within Divisions

There was no statistically significant difference in distance covered (forwards, midfield, defence) within the three divisions 5 ($F = 0.35$, $P > 0.05$), 9 ($F = 4.20$, $P > 0.05$) and 13 ($P > 0.05$).

Comparison of Distance between Positions between First half v Second half

The mean distance covered was 3037 ± 365 m for forwards first half, 2971 ± 507 m for forwards second half and 3323 ± 260 m for midfield first half, 3337 ± 319 m for midfield second half and 2954 ± 309 m for defence first half, 2943 ± 523 m for defence second half , Figure 3.2, Appendix C. There was no statistically significant difference in the distance covered in positions forward between first and second halves ($P > 0.05$) as shown in Figures 3.3 to 3.5, Appendix C.

Comparison of Distance between Divisions, Positions First Half v Second Half

There was no statistically significant difference in distance covered in positions comparisons (forwards second half ($F = 2.38$, $P > 0.05$) midfield second half ($F = 1.45$, $P > 0.05$) and defence second half ($F = 0.98$, $P > 0.05$) between match halves and between divisions (5, 9, 13) ($P > 0.05$). In general the division 5 players covered more distanace than division 9 and 13 players in both first and second halves. See Table 3.2 for distances travelled.

Table 3.2. Comparison of Distance between Divisions, Positions First Half v Second Half

Distance (m)	Division 5	Division 9	Division 13
First Half Forwards	3254 ± 293	2933 ±401	2926 ±386
Second Half Forwards	3258 ± 499	2581 ±228	3074 ±562
First Half Midfield	3251 ±178	3362±220	3356±395
Second Half Midfield	3198±256	3266±310	3546±347
First Half Defence	2971±311	3103±224	2786±367
Second Half Defence	3155±602	3034±310	2639±593

Speed

Comparison of Speed between Positions

The mean speed by each individual player was 1.59 ± 0.16 m/s. The mean speed per position was 1.58 ± 0.14 m/s for forwards, 1.66 ± 0.12 m/s for midfield and 1.53 ± 0.19 m/s for defence. Midfield players had higher mean speed than forwards and defence. There was no statistically significant difference in speed comparisons between the three positions, forward, midfield and defence ($F = 2.12$, $P > 0.05$).

Comparison of Speed between Divisions

The mean speed was 1.63 ± 0.17 m/s for division 5, 1.59 ± 0.12 m/s for division 9 and 1.56 ± 0.19 m/s for division 13. Division 5 players had higher mean speed than players in division 9 and division 13. There was no statistically significant difference in speed comparisons between the three divisions 5, 9 and 13 ($F = 0.51$, $P > 0.05$).

Comparison of Speed between Divisions by Position

The mean speed was 1.68 ± 0.10 m/s for division 5 forwards, 1.50 ± 0.08 m/s for division 9 forwards and 1.55 ± 0.17 m/s for division 13 forwards. The mean speed was 1.63 ± 0.10 m/s for division 5 midfield, 1.65 ± 0.13 m/s for division 9 midfield and 1.70 ± 0.14 m/s for division 13 midfield. The mean speed was 1.55 ± 0.25 m/s for division 5 defence, 1.63 ± 0.10 m/s for division 9 defence and 1.43 ± 0.19 m/s for division 13 defence. There was no statistically significant difference in speed comparisons between forwards ($F = 2.13$, $P > 0.05$), midfield and defence between the three divisions 5, 9 and 13 ($P > 0.05$).

Comparison of Speed between Positions within Divisions

The mean speed was 1.68 ± 0.10 m/s for forward division 5, 1.63 ± 0.10 m/s for midfield division 5 and 1.55 ± 0.25 m/s for defence division 5. The mean speed was 1.50 ± 0.08 m/s for forward division 9, 1.65 ± 0.13 m/s for midfield division 9 and 1.63 ± 0.10 m/s for defence division 9. The mean speed was 1.55 ± 0.17 m/s for forward division 13, 1.70 ± 0.14 m/s for midfield division 13 and 1.43 ± 0.19 m/s for defence division 13. There was no statistically significant difference in speed comparisons of positions (forwards, midfield,

defence) within the three divisions 5 ($F = 0.58$, $P > 0.05$), 9 ($F = 1.97$, $P > 0.05$) and 13 ($P > 0.05$).

Comparison of Speed between Positions between First half v Second half

The mean speed was 1.56 ± 0.12 m/s for forwards first half, 1.54 ± 0.16 m/s for forwards second half and 1.64 ± 0.11 m/s for midfield first half, 1.63 ± 0.16 m/s for midfield second half and 1.53 ± 0.17 m/s for defence first half, 1.48 ± 0.21 m/s for defence second half. There was no statistically significant difference in speed comparisons in forwwards, midfield and defence between the first and second halves ($P > 0.05$).

Comparison of Speed between Divisions, Positions 1st Half v 2nd Half

There was no statistically significant difference in speed comparisons in positions, forwards second half ($F = 2.44$, $P > 0.05$) midfield second half ($F = 1.21$, $P > 0.05$) and defence second half ($F = 0.80$, $P > 0.05$) between match halves and between divisions ($P > 0.05$). No overall pattern emerged. The forwards in division 5 achieved the fastest speed, the midfield in division 13 and the defence in division 9. See Table 3.3.

Table 3.3 Comparison of Speed between Divisions, Positions 1st Half v 2nd Half

Speed (m/s)	Division 5	Division 9	Division 13
First Half Forwards	1.65 ± 0.10	1.53 ±0.10	1.50 ±0.14
Second Half Forwards	1.65 ± 0.13	1.43 ±0.10	1.55 ±0.19
First Half Midfield	1.60 ±0.08	1.70±0.08	1.63±0.15
Second Half Midfield	1.58±0.13	1.58±0.17	1.73±0.17
First Half Defence	1.53±0.21	1.63±0.10	1.45±0.17
Second Half Defence	1.53±0.26	1.55±0.13	1.38±0.22

Comparison of Distance covered between Forward, Midfield, Defence in various Speed Zones.

The data for distance was also categorised within speed zones, from zone 1 to zone 6. The different speed zones ranges are shown in table 3.4.

Table 3.4. Speed Zone ranges in metres/second

Zone	m/s	Movement Classification
1	0.0	Low Intensity - LI
2	3.6	Low Intensity - LI
3	4.2	Moderate Intensity - MI
4	5.4	Moderate Intensity - MI
5	5.7	High Intensity - HI
6	6.0	High Intensity - HI

The speed zone data is illustrated in Table 3.5. There was a statistically significant difference in distance covered between positions in the speed zones 3 to speed zones 6 ($P < 0.05$) see Figures 3.6 to 3.13, Appendix C. In zone 3 the only significant difference in mean distance covered was between forwards than the midfield ($P < 0.05$). In zone 4 there was a significant difference in mean distance covered between forwards and midfield ($P < 0.05$) and between midfield and defence ($P < 0.05$). In zone 5 there was a significant difference in mean distance covered between midfield and defence ($P < 0.05$) and between forwards and defence ($P < 0.05$). In zone 6 there was a significant difference in mean distance covered between forwards and midfield, ($P < 0.05$) and between forwards and defence ($P < 0.05$). The percentage of time spent in low intensity activity (zone 1 and 2) was 54 % for forwards, 50% for midfield and 57% for defence. The percentage of time spent in moderate intensity activity (zone 3 and 4) was 33% for forwards, 39% for midfield and 34% for defence. The percentage of time spent in high intensity activity (zone 5 and 6) was 13% for forwards, 11% for midfield and 9 % for defence.

Table 3.5. Comparison of Distance covered between Forward, Midfield, Defence in various Speed Zones.

Speed (m/s)	Forward	Midfield	Defence
Zone 1	789 ± 118	736 ± 134	825 ± 242
Zone 2	2445 ± 199	2565 ± 389	2519 ± 619
Zone 3	1077 ± 430	1358 ± 215	1138 ± 308
Zone 4	893 ± 311	1251 ± 185	852 ± 343
Zone 5	645 ± 159	671 ± 187	478 ± 164
Zone 6	141 ± 84	69 ± 61	50 ± 41

Heart Rate

Comparison of HR between Positions

The mean HR of each individual player was 165 ± 13 bpm. The mean HR per position was 165 ± 17 bpm for forwards, 169 ± 8 bpm for midfield and 162 ± 15 bpm for defence. Midfield players had higher mean HR than forwards and defence. There was no statistically significant difference in HR comparisons between the three positions ($P > 0.05$).

Comparison of HR between Divisions

The mean HR was 170 ± 9 bpm for division 5, 170 ± 10 bpm for division 9 and 157 ± 17 bpm for division 13. Division 5 and division 9 players had higher mean HR than players in division 13. There was no statistically significant difference in HR comparisons between the three divisions 5, 9 and 13 ($P > 0.05$).

Comparison of HR between Divisions by Position

The mean HR was 171 ± 7 bpm for division 5 forwards, 169 ± 13 bpm for division 9 forwards and 154 ± 23 bpm for division 13 forwards. The mean HR was 176 ± 2 bpm for division 5 midfield, 166 ± 8 bpm for division 9 midfield and 167 ± 8 bpm for division 13 midfield. The mean HR was 161 ± 10 bpm for division 5 defence, 174 ± 8 bpm for division 9 defence and 151 ± 16 bpm for division 13 defence. There was no statistically significant difference in HR comparisons between forwards, midfield and defence between the three divisions 5, 9 and 13. Forwards ($F = 1.32$, $P > 0.05$), Midfield ($P > 0.05$) and Defence ($F = 4.00$, $P > 0.05$),

Comparison of HR between Positions within Divisions

There was a statistically significant difference observed between positional groups within divisions in HR ($F = 4.75$, $P < 0.05$). The only significant difference was between division 5 midfield and defence as illustrated in Table 3.6 below and Figures 3.14 and 3.15, Appendix C ($P > 0.05$).

Table 3.6. Comparison of HR between Positions within Divisions

HR ($b \cdot min^{-1}$)	Division 5	Division 9	Division 13
Forward	171 ± 7	169 ±13	154 ±23
Midfield	176 ± 2	166 ±8	167 ±8
Defence	161 ± 10	174 ± 8	151 ± 16

Comparison of HR between Positions between First half v Second half

The mean HR was 164 ± 18 bpm for forwards first half, 165 ± 16 bpm for forwards second half and 165 ± 14 bpm for midfield first half, 173 ± 5 bpm for midfield second half and 162 ± 15 bpm for defence first half, 161 ± 15 bpm for defence second half. There was no statistically significant difference in HR comparisons in forwards, midfield and defence between the first and second halves ($P > 0.05$).

Comparison of HR between Divisions, Positions First Half v Second Half

The only significant differences were in first halves between midfield division 5 and division 9 ($P < 0.05$) and midfield division 5 and division 13 ($P < 0.05$). The significant differences are illustrated in Table 3.7 below and Figures 3.16 and 3.17, Appendix C. There was no other statisically signifcant difference in the HR in respect of forwards first half, forwards second half ($F = 0.67$, $P > 0.05$), midfield second half ($F = 3.19$, $P > 0.05$), defence first half, defence second half ($F = 3.57$, $P > 0.05$).

Table 3.7. Comparison of HR between Divisions, Positions First Half v Second Half

HR ($b \cdot min^{-1}$)	Division 5	Division 9	Division 13
First Half Forwards	172 ± 7.44	171 ±14	151 ±23
Second Half Forwards	170 ± 7	167 ±13	158 ±24
First Half Midfield	176 ±2	162±13	158±17
Second Half Midfield	175±2	168±6	175±4
First Half Defence	160±11	175±7	152±16
Second Half Defence	160±11	173±8	150±16

Chapter 4 - Discussion

Distance

The major findings in the current study with regard to distance travelled demonstrate that amateur female hockey players cover a mean distance of 6188 ± 781 m in 70 minutes. All midfield players cover a greater mean distance, 6660 ± 542 m, than all forwards and defence, a significant difference ($P < 0.05$). The forwards' distance covered was 90% of the distance covered by midfield and the defence was 89% of the distance covered by midfield. This supports the current study hypothesis that midfield cover greater distances and defence will cover the least distance.

Lythe and Kilding (2011) found that fullbacks covered significantly less total distance than all other positions. However, in contrast the current findings state that the distance covered between midfield and defence was significantly different though not between any other positions. Lythe and Kilding (2011) reported that the mean total distance covered per position for 70 minutes was 8160 ± 428 m. The current study shows a smaller distance covered. The fullbacks covered significantly less total distance than all other positions. ($P < 0.05$). Lythe and Kilding (2011) state the difference in physical outputs observed for some positions suggests position-specific conditioning is required at the elite level. In the current study it can only be speculated that the game intensity may have been lower due to tactical or motivational factors or related to physiological status.

Paun et al. (2008) also used Spi10 GPS units to measure the movement patterns and physiological demands of hockey match play in elite Australian domestic competition. The

average time that each player spent on the pitch during each match was 64 minutes and total distance covered by players during this time was 6419 ± 838 m, equating to 7021 m for a 70 minute period. According to MacLeod et al. (2007) the mean total distance covered in a match was 6819 ± 5.0 m. These findings are also in contrast to the data from the current study, where the value is smaller. The MacLeod et al. (2007) study monitored the activity profile of elite level female hockey players with international experience during competition and time spent in different motion categories. However, this total distance and match time was based on the participants completing 14 laps of a measured circuit (52 minutes) to replicate the average time and distance covered in a match, and may not be a true reflection of a typical hockey match.

Macutkiewicz and Sunderland (2011) demonstrated that elite women hockey players cover a mean distance of 5541 ± 1144 m in a 48 minute match. This equates to 8081 m over a 70 minute period. This is also in contrast to the data from the current study, again the distance value is smaller in the current study. The variance in match time to the current study is as a result of the substitutions and the mean playing time among the playing positions. However, the current study is again compared to elite competition level match play and therefore, it may likely show that a difference exists in physiological demands placed on players and different playing positions. As cited by Macutkiewicz and Sunderland (2011), Ekblom (1986), Reilly and Williams (2003), Reilly and Thomas (1976) the nature of team sport activity requires several aspects of fitness, including aerobic and anaerobic, muscular strength, flexibility and agility. The importance of each fitness component is a requirement particularly at elite level in order to perform at the highest standard. However, in the current study of amateur female level each fitness component can be affected, even by positional role

and tactical style of play. The current study data shows that it may be difficult to replicate the demands of an elite environment.

Gabbett (2010) states that midfielders covered greater distances (6,154 m) than strikers (6,931m) and defenders (6,643 m). In the current study the findings were similar as midfield covered greater distance (6,660 m) than forwards (6,009 m) and defence (5,896 m). His findings show that midfield covered most distance. This is in agreement with the current study, however, the defence distance was more than the forwards distance, whereas in the current study the defence are at the lower end of the spectrum for distance covered. Gabbett (2010) reported that players covered 6.6 km over the course of a match. In the current study the findings were very similar as players covered 6.2 km over the course of a match. Gabbett (2010) investigated the physiological demands of women's hockey competition and compared them to the demands of game-based training activities. His study suggested that in comparison to competition, game-based training sessions resulted in more time spent in low intensity activity and did not reflect the physiological demands of competition. These findings may highlight the difference in amateur level in the current study to that of an elite competitive environment where players must perform under pressure and fatigue. It is possible that these differences are because of the greater physical capacity or tactical strategies used at this level. The findings were however, closer to the findings of the current study compared to higher distances in other literature reviewed with 14.6% less distance covered by forwards, 27% less for midfield and 16% less for defence.

In comparison between divisions the higher division 5 players covered a greater mean total distance than players in lower divisions, though this was not significant ($P > 0.05$). The division 9 and 13 players covered 96% of the distance covered by division 5 players. In

comparison between positions the findings show that the division 5 forwards covered a greater mean total distance than forwards in lower divisions, though not significant ($P > 0.05$), however, lower division midfield and defence covered a greater mean total distance than the division 5 midfield and defence, though this was not significant ($P > 0.05$).

Jennings et al. (2012) when comparing international and national male hockey players demonstrated that the total distance travelled independent of positional groups was 9776 ± 720 m and 8589 ± 623 m for international matches and national level Australian hockey league matches respectively. This is in contrast to data reported in the current study as the distances covered are 63% and 72% less in the current study. They stated that within the national leagues there were no differences between strikers and midfield for total distance but the defenders covered less total distance (8.1 ± 3.6% and 8.4 ± 2.6 %; 36.1 ± 11.1% and 51.5 ± 12.1%, respectively). This concurs with the current study findings that defence will be at the lower end of the spectrum as they covered less distance than midfield and forwards. The main finding of this study was that international players covered a greater total distance than the national level competition. It seems that this study demonstrates that international hockey matches have greater physical demands than national level matches. This is similar if the findings in the current study are compared to distances covered by elite level players, with elite level covering greater distances. Jennings et al. (2012) also state that other factors may explain the differences in the activity demands between different competition levels. For example, differences in tactics, technical abilities or the quality of the opposition. However, in contrast when investigating differences between divisions at amateur level there are no significant differences in distance covered. This suggests that physical demands between divsions do not differ significantly.

In comparisons of forward, midfield and defence between match halves the results show that there was no significant difference ($P > 0.05$). Distance covered per position decreased by 2.2% for forwards, increased by 0.41% for midfield and decreased by 0.37% for defence. The distance decreased overall by 0.68% between the first half and second half. The current study showed that in comparing forwards, midfield and defence between divisions and between halves the division 5 forwards covered greater mean distance that forwards in the lower divisions both in the first and second halves, though this was not significant ($P > 0.05$). However, the lower division midfield covered greater mean distance than the higher division midfield both in the first and second halves, though this not was significant, ($P > 0.05$). In defence the division 9 defence covered greater mean distance than the other two divisions 5 and 13 in the first half, whereas, the division 5 defence covered a greater distance than the other divisons 9, 13 in the second half, though not significant, ($P > 0.05$).

Lythe and Kilding (2011) reported that the mean total distance covered per position for 70 minutes decreased by 4.8% from the first half (4179 ± 254 m) to the second half (3981 ± 301 m). Jennings et al. (2012) reported that the total distance covered decreased in the second halves across all positions in both the international (6.1 to 7.5%) and national matches (2.4% to 4.7%). MacLeod et al. (2007) reported a decline in high intensity exercise in the second half. By position this breaks down as a decrease by 2.18% for forwards, an increase by 0.41% for midfield and a decrease by 0.37% for defence between the first half and second half. The findings in the current study show an overall decrease of 0.68% in distance for all positions between first and second half. The figure is less than reported by the other authors, however, the results show a similar trend of a decrease in the second half.

Fatigue during the latter stages of team sport has been reported in other studies. Such a reduction in distance between halves has been reported in studies in soccer by Bangsbo, Norregaard and Thorsoe (1991) and Reilly and Thomas (1976). The findings of these studies demonstrated a reduction in distance covered in the second half compared with the first half. This may suggest an element of the presence of fatigue, or indeed it may be other factors, such as the perceived importance of the match and the match score. The current match score has been discussed by Bloomfield, Polman, Butterly and O'Donoghue (2005) suggesting that it may be responsible for much of the decrease in outputs towards the end of matches. It is suggested that games where the outcome has already been decided would have reduced outputs from both teams as compared to games where the teams were separated by just one goal.

Speed

The major findings in the current study with regard to speed demonstrated that the amateur female hockey players mean speed by individual player was 1.59 ± 0.16 m/s in 70 minutes. The results of the current study show that all midfield players have higher mean speed, (1.66 ± 0.12 m/s), than all forwards (1.58 ± 0.14 m/s) and defence (1.53 ± 0.19 m/s), though not significant ($P > 0.05$). The forwards' average speed was 95% and the defence was 92% of the midfield average speed. The hypothesis that midfield will achieve higher speeds and that defence will achieve lower speeds was supported in the current study findings.

These results can be compared with other literature reviewed and comparisons made. The literature reviewed concentrated on speed zones and levels of intensity. This can then be used to make comparisons on speed. In the current study distance covered in different speed

zones were categorised according to intensity of movement patterns. The speed zones categorised into zone 1 and zone 2 as low intensity activity (0.0 m/s to 3.6 m/s) zone 3 and zone 4 as moderate intensity activity (3.6 m/s to 5.4 m/s) and zone 5 and zone 6 as high intensity activity (5.4 m/s to 6.0 m/s). The percentage of time spent in low intensity activity was 54 % (3234 m) for forwards, 50% (3301 m) for midfield and 57% (3344 m) for defence. The percentage of time spent in moderate intensity activity was 33% (1970 m) for forwards, 39% (2609 m) for midfield and 34% (1989 m) for defence. The percentage of time spent in high intensity activity was 13% (787 m) for forwards, 11% (741 m) for midfield and 9 % (528 m) for defence.

The current study showed that in comparing distance covered by forwards, midfield and defence between various speed zones that there was a statistically significant difference in distance covered between forwards and midfield in zone 3 moderate intensity, ($P < 0.05$). The forwards' distance covered at moderate intensity was 79% of the midfield distance. There was a significant difference between forwards and midfield ($P < 0.05$) and between midfield and defence ($P < 0.05$) in zone 4 moderate intensity. The forwards distance at moderate intensity, zone 4 was 71% and the defence was 68% of the distance by midfield. There was a significant difference between midfield and defence ($P < 0.05$) and between forwards and defence ($P < 0.05$) in zone 5 high intensity. Defence showing 71% of distance covered by midfield and 74% of distance covered by forwards in zone 5 high intensity. There was a significant difference between forwards and midfield ($P < 0.05$) and between forwards and defence ($P < 0.05$) in zone 6 high intensity. The midfield distance covered was 49% and the defence was 36% of the distance covered by forwards in zone 6 high intensity.

According to Boyle et al. (1994) hockey is intermittent in nature and is characterised by variable speeds of high intensity and separated by periods of low intensity recovery. These findings are similar to the current study which also shows differences in distance covered in different intensity activities. Most of the studies reviewed focus on the frequency and duration of sprint activities and activity patterns of players and the time spent in different motion categories. Changes in movement patterns and speed is an important aspect in providing an insight into team sports. This information will facilitate the development of appropriate training programmes and builds on existing knowledge.

In various studies player movement patterns were categorised into different speed zone ranges and classifications. Player activity was grouped in six zones mentioned above similiar from those defined by Gabbett (2010). He categorised movement velocity bands, corresponding to low intensity (0-1 m/s), moderate intensity (1-3 m/s and 3-5 m/s) and high intensity (5-7 m/s and > 7 m/s) activities. Lothian and Farrally (1994) used nine discrete movements and classified low intensity actvity as standing, walking backwards/sideways and jogging, noting that jogging backward/sideways, cruising backward/sideways, sprinting and activity with the ball as high intensity activity. Boddington et al. (2002) recorded player's positions at 15 second intervals to calculate displacement and then categorised them into movement categories. MacLeod et al. (2007) defined low intensity as standing, walking, jogging and defined high intensity as cruising, sprinting and lunging. Spencer et al. (2004) defined player motions into five different categories, standing, walking, jogging, striding and sprinting. Caution is necessary in comparing the data in the current study with results from other literature because different categorisations were used and some studies have combined the motion ranges into different parameters. However, a comparison of findings in the

current study against other literature can be used as an indication in the range of results identified and differences casued by different methods of data collection.

MacLeod et al. ((2007) defined low intensity as standing, walking, jogging and players spent 92.1 ± 7.4% of time in low intensity (11.4% standing, 45.1% walking and 35.6% jogging). MacLeod et al. (2007) defined high intensity as cruising, sprinting and lunging and accounted for 7.9 ± 1.2% of time in high intensity (5.1% cruising, 1.5% sprinting and 1.3% lunging). They stated that the only positional variation in time spent in each movement category occurred between defence and forwards, with the defence spending significantly less time walking than forwards. In the current study the data is in relation to distance covered, therefore, the figures cannot be compared to the time spent in the different activity intensities. It can be identified in the current study that players spent 54% of total distance covered in low intensity, 35% of total distance covered in moderate intensity and 11% of total distance in high intensity.

Macutkiewicz and Sunderland (2011) reported that the percentage of time midfield spend performing high intensity exercise was greater than that of defence. Walking accounted for a lower percentage of distance covered by forwards (25 ± 3.6%) than midfield (31.4 ± 4.1%) and defence (33.6 ± 2.3%) and there was a greater percentage of distance covered in sprinting by forwards (5.1 ± 2.3%) than defence (3.8 ± 1.5%). The data demonstrated that forwards had notably different activity patterns than midfield and defence. In the current study midfield had higher mean total speed (1.66 m/s) than forwards (1.58 m/s) and defence (1.53 m/s). The data is in agreement with forwards showing a different activity pattern to midfield, with forwards showing a greater percentage of distance 54% in low intensity to 50% for midfield, however, not as compared to defence which showed a higher percentage of 57%.

The data in the current study is in agreement with Macutiewicz and Sunderland (2011). Although the activity characteristics used to describe the intensity of exercise differs in the current study the findings are consistent to state that forwards cover greater percentage of distance than midfield and defence in high intensity activities.

Mohr, Ellingsgaard, Andersson, Bangsbo and Krustrup (2003) cited byJennings et al. (2012) and Gabbett (2010) state that the amount of high speed running is an important discriminator between elite and subelite team sport athletes. The main finding of the studies was that international players completed more high speed running across all positions than players at elite national level. They reported that players in international competition had a 10.1% greater multistage fitness test performance than those competing at the national level. This difference in aerobic fitness between international and national level players can be cross referenced with the current study. In the current study it can be stated that players were competing at amateur level and therefore, the aerobic fitness may be substiantially less than players at elite level. This can account for differences in the findings between the literature reviewed and the current study findings.

Lythe and Kilding (2011) reported that the major proportion of distance was covered at low and moderate intensities. The total distance covered was predominantly made up of low speed running (60.9% in zones 1 and 2) and moderate speed running (33% in zones 3 and 4). Despite differences in measurement of speed zone intensity ranges, there are similiarities with the current study whereby the greater percentage of distance covered 54% was in low intensity activity and 35% in moderate intensity activity. Lythe and Kilding (2011) state that hockey, like many team sports, is essentially a low intensity activity, interspersed with varying bouts of high intensity activity.

The data presented for speed in the current study is comparable in general to some of the findings of the other literature reviewed and available. According to the research from previous studies mentioned above most players spend most of their game time engaged in low intensity exercise. The findings in the current study did not specify differences in the number of sprints or the percentage of time engaged in each category of high intenstiy versus low intensity activities. The current study is in agreement with literature reviewed, whereby players spent most distance covered engaged in low intensity exercise, therefore it can be hypothesised that players spend most of their time engaged in low intensity activity. Although the current study has investigated the movement patterns in different intensities a limitation of the current study may likley be in the description of movement intensity ranges as compared to literature reviewed.

Heart Rate

The major findings in the current study with regard to HR responses demonstrated that amateur female hockey players mean HR of each individual player was 165 ± 13 bpm over 70 minutes. The results of the current study show that all midfield players have higher mean HR, (1.69 ± 17 bpm), than all forwards and defence, though this was not significant ($P > 0.05$). The defence HR was at the lower end of the spectrum, (1.62 ± 15 bpm). The forwards' HR was 98% and the defence 96% of the HR recorded for midfield. The hypothesis that midfield will achieve higher heart rates and defenders will achieve lower heart rates was supported in the current study findings.

Average HRs of 158 ± 8 bpm have been reported by Boyle et al. (1994) and 157 ±15 bpm by Ghosh, Goswami, Mazumdar and Mathur (1991), 155 ± 12 bpm by Johnston et al. (2004) and

176 ± 13 bpm by Paun et al. (2008) for elite men's hockey as cited by MacLeod et al. (2009). Lythe and Kilding (2011), Macutkiewicz and Sunderland (2011) stated positional differences in mean HR, indicating defenders had a higher mean heart rate than midfield. The findings from these studies are in contrast with the current study of 165 bpm, where the findings are lower by 2.5%. In the current study midfield had higher mean HRs than forwards and defence, though not significant ($P > 0.05$). The current study found that players in the higher division had higher mean total HR's to other lower division players, with significant differences between midfield and defence in the first half between division 5 compared to division 9 and 13.

Konarski et al. (2006) studied defence tactics to examine HR responses and estimate energy expenditure of hockey played in two different team defence tactics in two matches. The results suggested that the zone marking system (match 2) is less loaded than the man-to-man marking system (match 1) as regards HR. The mean value of the HR was 131 ± 9 and 124 ± 10 in the first match and second match respectively. The data also showed that the mean value of HR in every position decreases (5.28%) during the second match. This is in contrast with the current study where the mean total HR was higher (165 ± 13 bpm), a difference of (26.9%) compared to their study. The maximal HR was lower in the current study as compared to the findings of Konarski et al. (2006), a difference of (1.6%) compared to their study. The results per playing position are also in contrast to the current study, where the mean total HR was higher for all positions as compared to the study by Konarski et al. (2006), 29.7% for forwards, 28.0% for midfield and 24.6% for defence. A possible explanation for the difference in HRs may likely be as a result of the difference in physical fitness and fatigue of the players between the studies, as male elite level players are compared to amateur female club level players. Another possible factor may be the duration of the

matches, as match play time is not specified in this study and it could be assumed that the amount of match play time is different as compared to the current study, where all matches were of 70 minutes duration.

Lythe and Kilding (2011) reported that the mean HR during match play was 161 bpm, or 85.3 ± 2.9% $HR_{max.}$ Peak HR during matches was 196 bpm or 96.3 ± 2.7%. These figures are similar, however, lower (2.5%) than the current study figure of 165 bpm.

In comparisons of positions of forward, midfield and defence between match halves the results show that there was a higher mean HR for midfield than forwards and defence between first and second halves, though not significant ($P > 0.05$). The defence mean HR's were at the lower end of the spectrum. Heart rates per position increased by 0.6% for forwards and 4.8% for midfield and decreased by 0.6% for defence between first and second halves. The overall HR increased by 1.2% between the first half and the second half. The current study showed that in comparing forwards, midfield and defence between divisions and between halves the division 5 forwards had higher mean HR than forwards in the lower divisions both in the first and second halves, though this was not significant ($P > 0.05$). However, there was a significant difference (increase) in the HR in midfield between the first half and between division 5 and division 9 ($P < 0.05$) and division 5 and division 13 ($P < 0.05$). The division 5 and 13 midfield had a higher mean total HR to division 9 midfield in the second half, though not significant ($P > 0.05$). The division 9 defence had a higher mean HR to both division 5 and division 13 defence in both halves, though not significant ($P > 0.05$).

MacLeod et al. (2007) reported the average HR over the duration of a game of 48.5 ± 12.7 minutes was 172 ± 11 bpm. This is in contrast to 165 bpm in the current study, a 4% increase in average HR as compared to the current study. In the current study midfield had a higher mean HR than forwards and defence between first and second halves, though not significant. ($P > 0.05$). The defence HRs were at the lower end of the spectrum. HRs per position increased by 0.06% for forwards, 4.8% for midfield and decreased by 0.06 % for defence between first and second halves. Macleod et al. (2007) reports that there was a significant decrease in the average HR of players in the first half (174 ± 12 bpm) compared to the second half (169 ± 11 bpm) and there were no positional differences in HR. This is in contrast with the current study results where there is a 1.2% increase (164 bpm to 166 bpm) in HRs between match halves. There may be a combination of possible factors for the differences in results between the current study and the studies mentioned. A possible explanation for the difference in HRs may likely be as a result of the difference in physical fitness and fatigue of the players between the studies and there were no substitutions made. Elite female level players during competition are compared to amateur female club level players. The duration of the matches may also be a factor as match play time is less in this study as compared to the current study, where all matches were of 70 minutes duration. The climatic conditions could also have a bearing on the physical outputs. The current study was carried out during the winter season with harsher climatic conditions of cooler temperatures of wind and rain, therefore, this could effect the output of players and the results. The differences between intensities as measured by HR has been commented on by other studies and suggestions such as the effects of pyschological arousal and anxiety on match HR and the physiological costs of specific movements are noted as factors by Paun et al. (2008).

Lythe and Kilding (2011) reported a non signifcant decrease in mean HR between first (86.7%) and second halves (84.4%). In the current study the mean total HR increased by 1.2% between match halves. Lythe and Kilding (2011) state that strikers had significant lower mean HR than inside forwards. In the current study there was a significant difference in HR between division 5 midfield and division 5 defence (176 bpm, 161 bpm). Whereas, in the lower divisions the results were in contrast, with the defenders and midfield showing a higher mean total HRs than the other positions, though not significant. There was a significant difference in mean HR in midfield between the first half and between division 5 and division 9 and between division 5 and division 13. Lythe and Kilding (2011) suggest that their study is the first to present detailed $\%HR_{max}$ data for elite hockey. They recorded maximal fitness tests one week prior to the study to draw comparisons with the game situation. Therefore, the data comparisons with the current study are not possible for all data results and relative exertion. The number of players in the studies and lack of information regarding HR_{max} means that variation in individual HR may be responsible for some of the differences.

According to Lythe and Kilding (2011) a decrease in HR between first and second halves is a common finding in studies of team sports and this is suggested to be related to decreasing physical outputs, either through changes in game tactics or player fatigue. In the current study the overall HR between halves increased by 1.2%, with midfield showing the biggest increase of 4.8 % compared to forwards 0.6% and defence decreasing by 0.6%. The previous studies findings are in contrast with the midfield and forwards findings from the current study. It is noted above the combination of factors and possible limitations that exist in the findings of the current study which could explain the differences in results.

A variety of methods have been used in the current study to evalute the physiological demands of hockey, including assessment of HR response. The measurement of a physiological output such as HR displays an internal picture of the body's reaction to physical loads. The HR gives some information about the energy system used. According to Astrand, Rodahl, Dahl and Stromme (2003) cited Konarski et al. (2006) monitoring HR is used to control adaptation changes during a training process and qualify the types of exercise to prepare better individual exercise loads for competitors. They classified exercise as extremely heavy, if the HR amounted to150 bpm. The mean maximal HR of each indivudual player in the current study of 183 bpm and mean total HR 165 bpm therefore indicate the high physiological requirements of the game. Despite the intermittent nature of team sports, Esposito, Impellizzeri, Margonato, Vanni, Pizzini and Veicsteinas (2004) stated that HR response during match play provides a valid and useful measure of physiological strain. The mean and maximum HRs in the current study suggest a very high level of physical exertion. The higher HRs may also suggest less physical fitness among players in the current study.

Lythe and Kilding (2011) quantified a range of physical variables to describe the physical demands of hockey players at elite level. In the study Lythe and Kilding (2011) tested male hockey players and reported that they were heavier, taller and leaner than hockey players reported in previous studies by Boyle et al. (1994), Ghosh et a.l (1994), Johnston et al. (2004) and Spencer et al. (2004). They also reported that they were in final stages of preparation for a major tournament and were at higher fitness levels. These are important factors that cannot be dismissed and may likely account for such variances in results between this study and the current study. In the current study the players were female amateur players of various ages ranges between 18 to 50 and also in the early stages of the hockey season. In the current

study there were no substitutions made to players. These variables may likley account as possible explanations for differences in the HR findings.

It is suggested by Coyle (2004) that dehydration affects HR. Coyle (2004) stated that dehydration in exercise appears to have a robust effect on cardiovascular strain and that for every 1% of body weight loss due to dehyration, HR increases by 5-8 bpm and cardiac output declines significantly. However, in the current study a comparison of bodyweight pre and post match was not monitored, therefore, it is not possible to suggest that there was a negative impact on physical or cognitive performance as a result of dehydration. It is also suggested by Astrand and Saltin (1961) that emotion may have an effect on HR. However, they suggest that the influence that emotion has on HR is neutralised at high workloads. It may likely be that the most significant reasons for a difference are related to the additional physiological demands of movement tempo changes in the game, match specific movements and body positions.

Discussion Conclusions

It is clear that the physiological demands of team sports are affected by several factors, such as competitive standard, physical fitness and playing position. The onset of physical fatigue and factors relating to fitness such as depletion in muscle glycogen stores due to fitness levels may be a factor among the participants in the current study. In the current study the amateur players and may not have been as well conditioned to the physiological demands as compared to elite level hockey players. Indeed, the players for the current study were only a few weeks into the start of the hockey season, therefore, it can be speculated that they were not in peak condition compared to players that had been training consistently and playing regular

matches for a number of months. Rampanini, Coutts, Castagna, Sassi and Impellizzeri (2007) reported that distances covered in professional soccer were greater at the end of a season as compared to the start of the season. There is also the difference of the physiological demands in gender between the studies. Factors such as the score line, motivation, amount of game time and tactical changes may influence match intensity and consequently have the effect of lower or higher results in movement and intensity.

MacLeod et al. (2007) states that the ability to sustain exercise for a prolonged period of time is dependent on a high maximal aerobic power and anaerobic threshold. The variations in player characteristics and physiology may have influenced the results of the current study. It may be influenced by such factors as the ability of the players, the playing style of the players, opposition, changes in team tactics within games, the environmental conditions, and the results of the games.

A number of factors can influence work rate. The style of play, as in, time in possession of the ball, pace of the game and formation will also influence the work rates of players. According to Lothian and Farrally (1994) high intensity activites and activities in which the player is directly involved with the ball (for example, dribbling) have been shown to represent between 17.5% to 30% of the competition time. In the current study the different playing standards, style of play and ball possession may have influenced the degree of intensity and the difference in distance travelled between players and divisions. In the current study higher division players in midfield and defence covered less distance than lower division midfield and defence. This may be due to more tactically and technically skilled players' efficient use of the ball through efficient quick passing and better positioning. This

could be compared to lower division players running with the ball or loosing the ball to the opposition as they are less tactically and technically skilled players.

Some of the variations could be accounted for by differences in age profile, tactical skill and tactics of the game (greater use of ball), tactics of opposition, technical skill, decision making, profile of specific positions, no substitutions resulting in greater fatigue, fitness status, physical qualities, weekly training duration and programmes. Furthermore, the physical outputs of players in the current study were compared with those at international level of many years of experience, with training specificity and conditioning, Therefore, the player characteristics in the studies reviewed do not simulate the same physiologoical demands needed at amateur level. In the current study there may be reason to expect that reliability and variability of the results is influenced by the participants' youth or sex. Other characteristics such as heterogeneity, motivation to do well may be factors that effect reliability and variability of results.

The variability in physiological demands between the current study and previous studies mentioned may reflect differences in competitive standard, sports, gender, physical condition, and perhaps if players are injury free at the time of the study. The present study is compared with elite men and elite women with international experience. According to MacLeod et al. (2009) match analysis of hockey has demonstrated that there is a large degree of inter and intravariability in the work rates of players. Moreover, every match is different and even in a standardised setting physical outputs will vary. The rules of hockey allow for continuous substitutions to be made throughout the match, which enables players to recover after high-intensity bouts of activity. However, the opportunity to rest may be position dependent in that only forwards and midfield rotate on a regular basis, unless changes in team tactics and

strategy are required. In the current study there were no substitutions made, this is most likley due to the amateur playing level, restrictions in the number of player positions, coaching strategies, team and opposition strategy and player availability on a given match day.

Quantification of the outputs of players provides a useful framework on which to develop and plan training practices, performance, substitution, while also helping to motivate players, promote more competition, boost morale, tactical solutions with reference to players' capabilities. Lythe and Kilding (2011) state that fullbacks covered significantly less total distance than all other positions. The difference in physical outputs observed for some positions suggests position-specific conditioning is required at the elite level. Gabbett (2010) states that midfielders covered greater distances than strikers and defenders. Lythe and Kilding (2011) state that such a high frequency of tempo changes suggests that caution is needed when simply using distance covered to assess the physical demands of elite hockey, as considerable amounts of additional energy are utilised during accelerating and decelerating movements and when running backwards and laterally.

Although differences may exist between distance, speed and HR within positions the coach may be more interested in the similarities that do exist. From a practical point of view a coach may decide that these differences do not indicate the need for position specific training at female amateur level. The results suggest that similiar fitness requirements may be sufficient across all positions at this level.

The research has shown that differences are evident in the distance covered in low, moderate and high intensity speed zones. A possible explanation for the higher speed for midfield may

likley be as a result of the immediate switch between attack and counter attack tactics and method of play that midfield players are engaged in. Midfield players need the ability to react quickly to attack and counterattack and change direction between defence and forward without loss of speed or while maintaining high speeds. An explanation for forwards' greater speed in the higher division may likely be as a result of the forwards making high intensity sprints into space to escape away from the opposition defence. In the lower divisions the lack of speed may be as a result of weaker technical skills of dribbling the ball without losing running speed. According to Lemmink, Elferink-Gemser and Visscher (2004) for a technically good player, dribbling is essentially an automatic skill, and the better players distinguish themselves by their running speed while dribbling the ball. It should be noted that few differences occurred between midfield and forwards in terms of speed and work rate, which may highlight a change in modern tactics to a more fluid attacking formation involving frequent interchange and player versatility.

Direct comparison with these previous studies is difficult because of the different match analysis methods used, differences in player characteristics, physical condition and the differences in the status of the players. Further research that could investigate the relationship between technical/tactical skills, similar status and physical performance is required to elucidate these positional differences. Players at amateur level may require additional conditioning to achieve the higher physical outputs and higher aerobic capacity required if aspiring to elite and international level. Finally, emphasis should be placed in the individualisation of conditioning programmes to address the specific demands of the different playing positions.

In order to identify the demands placed on players it is also important to take into consideration the factor that any one individual's play and performance in a game may also be constrained by their fitness. The aim of the research in the current study was to observe physical demands of amateur female hockey players. The main objective was to compare distance travelled, speed and HR between the three playing positions (forward, midfield, defence). The research was to find out, if at all, if the three variables differ. The current study hypotheses that midfield will cover greater distance, will achieve higher speed and will achieve higher HR is in agreement with the findings. The defence covered the least total distance, had the lowest average speed and the lowest average HR responses.

This analysis of amateur female hockey suggests that players and positions require a high level of conditioning due to large distances covered, high speed and bursts of high intensity running and a variety of additional physical demands associated with the game even at amateur level.

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Appendices

Appendix A – Additional Research

Table 1.1. The key benefits of GPS technology for Field Hockey include:

Accurately Quantify Training Load	How much work a player has done in a given session. • Objectively assess loading across a range of intensities for distance, speed, acceleration, heart rate and impacts.
Quantify Work Rate	Easily compare training drills to game intensity. • Use this information to guide training structure, manage overload, manipulate drills and educate coaches.
Compare Individual Players	Compare players across a range of performance measures in training and game. • Use this information to target outliers in the group, assess strengths and weaknesses of individual players and quantify changes under fatigue.
Maximise Performance and Minimise Injury	By understanding actual on field loads. • Better estimate recovery timeframes. • Better integrate types of training – speed, conditioning, strength, power, cross training. • Accurately periodise cycles of training. • Accurately assess and monitor players during rehabilitation.
Instant Information	Get live training data streamed to a mobile device during training. This allows on field and make informed decisions regarding, • The accumulation of load during a training session • High risk players on restricted training loads • Feedback and instruction to coaches and players The manipulation of training to achieve desired outcomes – For example assess heart rate response of the team and immediately modify work to rest ratios, drill sizes and or drill rules to change physical requirements
Improve Understanding of the Game	Collate game data to benchmark positional demands. • Use this information to prioritise the athletic development of players. • Compare data with other teams and levels of competition to identify areas for improvement.

Appendix B – Additional Materials

Title of Project: Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players

Name of Researcher: Angie Boran

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

3. I agree to take part in the above study. ☐

_____	_____	_____
Name of Participant	Date	Signature

_____	_____	_____
Researcher	Date	Signature

1 for participant; 1 for researcher

Letter of Invitation to Participant

To Whom It May Concern

Re: Research Project. Name of Researcher: Angie Boran
Title of Project: Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players.

I am completing a Master of Science in Exercise and Nutrition Science. As part of my studies I will be completing a research project. The research is conducted within the Department of Clinical Services at the University of Chester. I am writing to you to invite you to participate in this study.

What is the purpose of the study?
This research is being undertaken on amateur female hockey players. The project is to find out how, if at all the, distance travelled, speed and heart rate differs between three outfield positions (forwards, midfield, defence).

The use of global positioning system (GPS) devices to measure demands in team sports is becoming increasingly popular. A better understanding of these demands will help both players and coaches understand and plan specific training programs, performance and tactical solutions. Quantification of the outputs of players will provide a useful framework with reference to players' capabilities. It will provide useful and interesting information for you as a player and the club.

The research methods will take the form of a structured questionnaire and 36 players will be asked to participate during one hockey match. During the game your distance travelled, speed and heart rate will be measured. You will wear a SPIproX GPS tracking unit and will play your game as normal. No-one will be identifiable in the final report. There are no disadvantages or risks foreseen in taking part in the study as you will be playing a hockey game as normal.

Please don't hesitate to ask me if there is anything that is not clear or if you would like more information.

Thank you for taking interest in this research.

Yours sincerely

_____
Angie Boran

Participant information sheet

Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for reading this.

What is the purpose of the study?
This research is being undertaken on amateur female hockey players. The project is to find out how, if at all the, distance travelled, speed and heart rate differs between three outfield positions (forwards, midfield, defence).

The use of global positioning system (GPS) devices to measure demands in team sports is becoming increasingly popular. GPS have the potential to further our understanding of the physiological demands in sport. Speed and endurance are the important abilities for successful athletic performance. A better understanding of these abilities will help both players and coaches understand and plan specific training programs, performance and tactical solutions. Quantification of the outputs of players will provide a useful framework with reference to players' capabilities.

Why have I been chosen?
You have been chosen because you are an amateur female hockey player and meet the criteria of the study.

Do I have to take part?
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect you in any way.

What will happen to me if I take part?
You will be given this information sheet to keep and asked to sign the consent form. You will complete a structured questionnaire to obtain some health and baseline characteristics . You will participate in 1 hockey match. During the game your distanced travelled, speed and heart rate will be measured. You will be asked to wear a SPIproX GPS tracking unit, where you will be asked to play your game as you normally would. The GPS unit is inserted into a purpose built vest and a heart rate monitor is worn. The GPS unit is flat in design and is

48mm x 20mm x 87mm. It is lightweight and weighs 76grams. No-one will be identifiable in the final report.

What are the possible disadvantages and risks of taking part?
There are no disadvantages or risks foreseen in taking part in the study. You will be playing your game as normal.

What are the possible benefits of taking part?
By taking part, you will be contributing to the development of the quantification of the outputs of players. This will provide a useful framework on which to develop and plan training practices, performance, substitution, while also helping with motivation, promote more competition, tactical solutions with reference to players' capabilities. It will provide useful and interesting information for yourself and all club members.

What if something goes wrong?
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the Faculty of Applied Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 0044 1244 513055.

Will my taking part in the study be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

What will happen to the results of the research study?
The results will be written up into a dissertation for my final project of my MSc. Individuals who participate will not be identified in any subsequent report or publication.

Who is organising the research?
The research is conducted as part of a MSc in Exercise & Nutrition Science within the Department of Clinical Sciences at the University of Chester. The study is organised with supervision from the department, by Angie Boran, an MSc student.

Who may I contact for further information?
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:
Angie Boran.

Thank you for your interest in this research.

Pre-test Questionnaire 1

Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players

Researcher *: Angie Boran*

Name:_____

Contact Number:_____ **Occupation**:_____

Date of Birth:_____ **Height**: _____ **Weight**:_____

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1	Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?	YES/NO
2	Do you feel pain in the chest when you perform physical activity?	YES/ NO
3	In the past month, have you had chest pain when you were not performing physical activity?	YES/ NO
4	Do you lose your balance because of dizziness or do you ever lost consciousness?	YES/ NO
5	Do you have bone or joint problems (e.g. back, knee or hip) that could be made worse by a change in your physical activity?	YES/ NO
6	Is your doctor currently prescribing drugs for your blood pressure or heart condition?	YES/ NO
7	Are you currently taking any inhaler treatments for asthma?	YES/ NO
8	Are you pregnant, or have you been pregnant in the last six months?	YES/ NO
9	Do you have any injuries currently or in the last year?	YES/ NO
10	Do you know of any reason why you should not participate in physical activity?	YES/ NO

Thank you for taking your time to fill in this form.

Pre-test Questionnaire 2

Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players

Researcher *: Angie Boran*

Name:_____

Contact Number:_____ **Occupation**:_____

Date of Birth:_____ **Height**: _____ **Weight**:_____

In order to ensure that this study is as safe and accurate as possible, it is important that each potential participant is screened for any factors that may influence the study. Please circle your answer to the following questions:

1	Do you currently smoke?	YES/NO
2	Do you work in a job that is physically demanding?	YES/ NO
3	How many days per week do you exercise/train?	1 2 3 4 5 6 7
4	Do you take part in any other exercise?	Running / Swimming/ Cycling / Camogie/ Football/ Tennis/ Other
5	How would you describe your current level of fitness?	Very Fit / Fit / Average Unfit/Very Unfit
6	Which position do you normally play?	FWD / MID / DEF
7	How many years have you being playing hockey?	1-4 5-10 11-20 21-30 >30
8	What hockey division do you play in?	

Thank you for taking your time to fill in this form.

University of Chester

Faculty of Applied Sciences
Research Ethics Committee

Tel 01244 511740
Fax 01244 511302
frec@chester.ac.uk

Angie Boran
[redacted]

23rd April 2012

Dear Angie,

Study title: **Comparison of distance travelled, speed and heart rate among three outfield positions in amateur female hockey players.**
FREC reference: **621/12/AB/CS**
Version number: 1

Thank you for providing the documentation for the amendments recommended following the approval of the above application. These amendments have been approved by the Faculty Research Ethics Committee with the recommendation that the personal contact email address provided on the poster is replaced with your University email address.

With the Committee's best wishes for the success of this project.

Yours sincerely,

Cynthia Burek

Prof. Cynthia Burek
Chair, Faculty Research Ethics Committee

2011FREC B
Approval letter – 2010/11

20th July 2011

Irish Hockey Association
FAO Fiona Mills and Lucas Piccioli
National Development Officers

Re: Research Project. Name of Researcher: Angie Boran
Title of Project: Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players.

I am completing a Master of Science in Exercise and Nutrition Science. As part of my studies I will be completing a research project. The research is conducted within the Department of Clinical Services at the University of Chester. They have asked me to inform you that i am doing this and would the IHA have any objection. I will be using hockey players in Botanic Hockey Club as potential participants for my research project.

What is the purpose of the study?
This research is being undertaken on amateur female hockey players. The project is to find out how, if at all the, distance travelled, speed and heart rate differs between three outfield positions (forward, midfield, defence).
The use of global positioning system (GPS) devices to measure demands in team sports is becoming increasingly popular. A better understanding of these demands will help both players and coaches understand and plan specific training programs, performance and tactical solutions. Quantification of the outputs of players will provide a useful framework with reference to players' capabilities. It will provide useful and interesting information for the club.
The research methods will take the form of a structured questionnaire and 36 players will be asked to participate during one hockey match. During the game their distanced travelled, speed and heart rate will be measured. The players will wear a SPIproX GPS tracking unit and will play their game as normal. No-one will be identifiable in the final report. There are no disadvantages or risks foreseen in taking part in the study as the players will be playing a hockey game for their club as normal.

Please don't hesitate to ask me if there is anything that is not clear or if you would like more information.

Thank you for taking interest in this research.

I would be obliged if you can just let me know if you would have an issue with this.

Yours sincerely

_____

Angie Boran
Botanic Hockey Club

YAHOO! MAIL
UK & IRELAND Classic

Re: Re; Research Project Monday, 25 July, 2011 13:31

From: "David Passmore" <dave.irishhockey@me.com>
To: "Angie Boran" <[redacted]>
Cc: "Lucas Piccioli" <Lucas.Piccioli@Hockey.ie>, "Mark Kilgallon" <[redacted]>

Angie,

We have no problem with you completing this research and you can quote my name. we are doing something similar with the elite players so would be interested in reading your research write up when you have completed it.

Kind regards,

Dave

David Passmore
High Performance Director
Irish Hockey Association
+353 87 9373750
dave.irishhockey@me.com
Skype: david.passmore5

On 25 Jul 2011, at 12:13, Lucas Piccioli wrote:

> Hi Angie,
>
> I am copying Dave Passmore on this email as I think that will fall more into high performance than actually development. If none of the players involved in your study are underage then you shouldn't be concerned about code of ethics.
>
> Let me know if there is anything else we can do to help and make sure I get a copy of the results of your research as it looks extremely interesting.
>
> Kind regards,
>
> **Lucas**
> Eastern Development Officer
> Newstead
> UCD
> Belfield
> Dublin 4
> Ph: 00353 1 7163266
> Fax: 00353 1 7163260
> www.hockey.ie
> ***Irish Hockey - Get Hooked!***

Club Captain
Botanic Hockey Club

To Whom It May Concern

Re: Research Project. Name of Researcher: Angie Boran
Title of Project: Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players.

I am completing a Master of Science in Exercise and Nutrition Science. As part of my studies I will be completing a research project. The research is conducted within the Department of Clinical Services at the University of Chester. I am writing to you to request permission to approach hockey players in Botanic Hockey Club as potential participants for my research project.

What is the purpose of the study?
This research is being undertaken on amateur female hockey players. The project is to find out how, if at all the, distance travelled, speed and heart rate differs between three outfield positions(forwards, midfield, defence).
The use of global positioning system (GPS) devices to measure demands in team sports is becoming increasingly popular. A better understanding of these demands will help both players and coaches understand and plan specific training programs, performance and tactical solutions. Quantification of the outputs of players will provide a useful framework with reference to players' capabilities. It will provide useful and interesting information for the club.
The research methods will take the form of a structured questionnaire and 36 players will be asked to participate during one hockey match. During the game their distanced travelled, speed and heart rate will be measured. The players will wear a SPIproX GPS tracking unit and will play their game as normal. No-one will be identifiable in the final report. There are no disadvantages or risks foreseen in taking part in the study as the players will be playing a hockey game for their club as normal.

Please don't hesitate to ask me if there is anything that is not clear or if you would like more information.

Thank you for taking interest in this research.

Yours sincerely

_____

Angie Boran

Botanic Hockey Club

www.botanichockeyclub.com

1/11/2011

Ms Angie Boran

To Whom It May Concern

Re: Research Project. Name of Researcher: Angie Boran
Title of Project: Comparison of Distance Travelled, Speed and Heart Rate among Three Outfield Positions in Amateur Female Hockey Players.

In reference to your request for permission to carry out a research project I would like to state that we have no problem with you completing this research study within Botanic Hockey Club.

We would be delighted to participate and look forward to viewing the outcomes of the research.

Yours sincerely

Orla Donnelly

Club Captain
Botanic Hockey Club

Appendix C - Additional Results

Post Hoc Tests

Multiple Comparisons

Distance m/s
Tukey HSD

(I) Positions	(J) Positions	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Forward	Midfield	-651.15833	295.12631	.085	-1375.3377	73.0210
	Defence	112.02833	295.12631	.924	-612.1510	836.2077
Midfield	Forward	651.15833	295.12631	.085	-73.0210	1375.3377
	Defence	763.18667*	295.12631	.037	39.0073	1487.3660
Defence	Forward	-112.02833	295.12631	.924	-836.2077	612.1510
	Midfield	-763.18667*	295.12631	.037	-1487.3660	-39.0073

*. The mean difference is significant at the 0.05 level.

Figure 3.1: Significant difference in distance covered between midfield and defence.

Test Statistics[a,b]

	Distance m	Speed m/s	HR bpm
Chi-square	11.527	8.068	7.518
df	5	5	5
Asymp. Sig.	.042	.153	.185

a. Kruskal Wallis Test

b. Grouping Variable: Match Halves

Figure 3.2: Significant difference in distance covered in positions between halves.

Mann-Whitney Test

Ranks

	Match Halves	N	Mean Rank	Sum of Ranks
Distance m	Forwards First Half	12	12.92	155.00
	Forwards Second Half	12	12.08	145.00
	Total	24		

Test Statistics[b]

	Distance m
Mann-Whitney U	67.000
Wilcoxon W	145.000
Z	-.289
Asymp. Sig. (2-tailed)	.773
Exact Sig. [2*(1-tailed Sig.)]	.799[a]

a. Not corrected for ties.

b. Grouping Variable: Match Halves

Figure 3.3: Distance covered between Forwards between halves.

Mann-Whitney Test

Ranks

	Match Halves	N	Mean Rank	Sum of Ranks
Distance m	Midfield First Half	12	12.67	152.00
	Midfield Second Half	12	12.33	148.00
	Total	24		

Test Statistics[b]

	Distance m
Mann-Whitney U	70.000
Wilcoxon W	148.000
Z	-.115
Asymp. Sig. (2-tailed)	.908
Exact Sig. [2*(1-tailed Sig.)]	.932[a]

a. Not corrected for ties.

b. Grouping Variable: Match Halves

Figure 3.4: Distance covered between Midfield between halves.

Mann-Whitney Test

Ranks

	Match Halves	N	Mean Rank	Sum of Ranks
Distance m	Defence First Half	12	12.50	150.00
	Defence Second Half	12	12.50	150.00
	Total	24		

Test Statistics[b]

	Distance m
Mann-Whitney U	72.000
Wilcoxon W	150.000
Z	.000
Asymp. Sig. (2-tailed)	1.000
Exact Sig. [2*(1-tailed Sig.)]	1.000[a]

a. Not corrected for ties.

b. Grouping Variable: Match Halves

Figure 3.5: Distance covered between Defence between halves

Test Statistics[a,b]

	Zone 1 m	Zone 2 m	Zone 3 m	Zone 4 m	Zone 5 m	Zone 6 m
Chi-square	1.459	.659	7.137	11.317	7.821	9.159
df	2	2	2	2	2	2
Asymp. Sig.	.482	.719	.028	.003	.020	.010

a. Kruskal Wallis Test

b. Grouping Variable: Positions

Figure 3.6: Comparison of distance between positions in various speed zones.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 3 m	Forward	12	8.83	106.00
	Midfield	12	16.17	194.00
	Total	24		

Test Statistics[b]

	Zone 3 m
Mann-Whitney U	28.000
Wilcoxon W	106.000
Z	-2.540
Asymp. Sig. (2-tailed)	.011
Exact Sig. [2*(1-tailed Sig.)]	.010[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.7: Distance covered between forward and midfield in zone 3.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 4 m	Forward	12	8.33	100.00
	Midfield	12	16.67	200.00
	Total	24		

Test Statistics[b]

	Zone 4 m
Mann-Whitney U	22.000
Wilcoxon W	100.000
Z	-2.887
Asymp. Sig. (2-tailed)	.004
Exact Sig. [2*(1-tailed Sig.)]	.003[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.8: Distance covered between forward and midfield in zone 4.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 4 m	Midfield	12	16.67	200.00
	Defence	12	8.33	100.00
	Total	24		

Test Statistics[b]

	Zone 4 m
Mann-Whitney U	22.000
Wilcoxon W	100.000
Z	-2.887
Asymp. Sig. (2-tailed)	.004
Exact Sig. [2*(1-tailed Sig.)]	.003[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.9: Distance covered between midfield and defence in zone 4.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 5 m	Midfield	12	16.00	192.00
	Defence	12	9.00	108.00
	Total	24		

Test Statistics[b]

	Zone 5 m
Mann-Whitney U	30.000
Wilcoxon W	108.000
Z	-2.425
Asymp. Sig. (2-tailed)	.015
Exact Sig. [2*(1-tailed Sig.)]	.014[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.10: Distance covered between midfield and defence in zone 5.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 5 m	Forward	12	15.92	191.00
	Defence	12	9.08	109.00
	Total	24		

Test Statistics[b]

	Zone 5 m
Mann-Whitney U	31.000
Wilcoxon W	109.000
Z	-2.367
Asymp. Sig. (2-tailed)	.018
Exact Sig. [2*(1-tailed Sig.)]	.017[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.11: Distance covered between forward and defence in zone 5.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 6 m	Forward	12	15.50	186.00
	Midfield	12	9.50	114.00
	Total	24		

Test Statistics[b]

	Zone 6 m
Mann-Whitney U	36.000
Wilcoxon W	114.000
Z	-2.079
Asymp. Sig. (2-tailed)	.038
Exact Sig. [2*(1-tailed Sig.)]	.039[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.12: Distance covered between forward and midfield in zone 6.

Mann-Whitney Test

Ranks

	Positions	N	Mean Rank	Sum of Ranks
Zone 6 m	Forward	12	16.83	202.00
	Defence	12	8.17	98.00
	Total	24		

Test Statistics[b]

	Zone 6 m
Mann-Whitney U	20.000
Wilcoxon W	98.000
Z	-3.002
Asymp. Sig. (2-tailed)	.003
Exact Sig. [2*(1-tailed Sig.)]	.002[a]

a. Not corrected for ties.

b. Grouping Variable: Positions

Figure 3.13: Distance covered between forward and defence in zone 6.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Distance m	Between Groups	342540.167	2	171270.083	.346	.716
	Within Groups	4452854.903	9	494761.656		
	Total	4795395.069	11			
Speed m/s	Between Groups	.032	2	.016	.582	.579
	Within Groups	.245	9	.027		
	Total	.277	11			
HR bpm	Between Groups	478.167	2	239.083	4.753	.039
	Within Groups	452.750	9	50.306		
	Total	930.917	11			

Figure 3.14: Significant difference in HR comparisons between groups.

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Positions	(J) Positions	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Distance m	Div5 Forward	Div5 Midfield	63.75000	497.37393	.991	-1324.9208	1452.4208
		Div5 Defence	386.00000	497.37393	.726	-1002.6708	1774.6708
	Div5 Midfield	Div5 Forward	-63.75000	497.37393	.991	-1452.4208	1324.9208
		Div5 Defence	322.25000	497.37393	.798	-1066.4208	1710.9208
	Div5 Defence	Div5 Forward	-386.00000	497.37393	.726	-1774.6708	1002.6708
		Div5 Midfield	-322.25000	497.37393	.798	-1710.9208	1066.4208
Speed m/s	Div5 Forward	Div5 Midfield	.05000	.11667	.905	-.2757	.3757
		Div5 Defence	.12500	.11667	.554	-.2007	.4507
	Div5 Midfield	Div5 Forward	-.05000	.11667	.905	-.3757	.2757
		Div5 Defence	.07500	.11667	.801	-.2507	.4007
	Div5 Defence	Div5 Forward	-.12500	.11667	.554	-.4507	.2007
		Div5 Midfield	-.07500	.11667	.801	-.4007	.2507
HR bpm	Div5 Forward	Div5 Midfield	-4.250	5.015	.685	-18.25	9.75
		Div5 Defence	10.750	5.015	.136	-3.25	24.75
	Div5 Midfield	Div5 Forward	4.250	5.015	.685	-9.75	18.25
		Div5 Defence	15.000*	5.015	.037	1.00	29.00
	Div5 Defence	Div5 Forward	-10.750	5.015	.136	-24.75	3.25
		Div5 Midfield	-15.000*	5.015	.037	-29.00	-1.00

*. The mean difference is significant at the 0.05 level.

Figure 3.15: Significant difference in HR comparisons between division 5 midfield and division 5 defence.

Mann-Whitney Test

Ranks

	Match Halves	N	Mean Rank	Sum of Ranks
HR bpm	Div 5 First Half Midfield	4	6.50	26.00
	Div 8,9 First Half Midfield	4	2.50	10.00
	Total	8		

Test Statistics[b]

	HR bpm
Mann-Whitney U	.000
Wilcoxon W	10.000
Z	-2.323
Asymp. Sig. (2-tailed)	.020
Exact Sig. [2*(1-tailed Sig.)]	.029[a]

a. Not corrected for ties.

b. Grouping Variable: Match Halves

Figure 3.16: Significant difference in HR in midfield between the first half and between divisions 5 and division 9.

Mann-Whitney Test

Ranks

	Match Halves	N	Mean Rank	Sum of Ranks
HR bpm	Div 5 First Half Midfield	4	6.50	26.00
	Div 11,12,13 First Half Midfield	4	2.50	10.00
	Total	8		

Test Statistics[b]

	HR bpm
Mann-Whitney U	.000
Wilcoxon W	10.000
Z	-2.323
Asymp. Sig. (2-tailed)	.020
Exact Sig. [2*(1-tailed Sig.)]	.029[a]

a. Not corrected for ties.

b. Grouping Variable: Match Halves

Figure 3.17: Significant difference in HR in midfield between the first half and between division 5 and division 13.